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THE INFLUENCE OF THE VEHICLE LAYOUT ON THE PERFORMANCE OF PUBLIC TRANSPORT

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Abstract

To meet growing demand and environmental policy requirements, it is important for local rail passenger transport to increase its performance. There are various options for this in the area of infrastructure. At the same time, the layout of the vehicles also has a significant influence on performance. Incorrectly planned vehicles lead on the one hand to a significant reduction in the capacity that can actually be achieved and on the other hand to an unnecessary increase in passenger changeover times. The longer passenger changeover time also means a longer train sequence time and therefore a reduction in performance on the line. The presentation shows which errors in the planning of night trains (underground trains, suburban trains, regional trains) lead to a reduction in efficiency as a result of the passenger changeover time and, conversely, which measures in the vehicles help to increase the efficiency of a line or network. At the same time, there is potential for energy savings.

Keywords: public transport efficiency, capacity, dwell time, energy efficiency

1 Method

All of the following findings are based on more than twenty years of research and implementation of around 40 research and consultancy projects, in which observations on trains from over 400,000 passengers, video time measurements of boarding passengers and our own series of tests in the vehicles and interviews with travellers were used to gather information, such as which seats are preferred, where and how luggage is stored, what difficulties arise when storing luggage or boarding and moving around in the vehicle. It was possible to comprehensively survey behaviour in relation to taking and storing luggage. Based on this extensive data, which exclusively considers the specific behaviour of passengers on trains, the software TrainOptimizer® was developed in cooperation with the Vienna University of Technology and netwiss, with the help of which vehicle layouts can be very easily assessed in terms of their efficiency by means of simulation. The findings presented in this paper are based in part on the use of simulations in TrainOptimizer®. Figure 1 shows the symbolic simulation flow chart. In a first step, layouts are created in an easy-to-use editor and then further settings such as deviating age distribution, special journey purpose mixes, region-specific data etc. are selected for the evaluation if required. Based on the extensive data available, the tool knows the luggage volume and the behaviour of travellers when boarding and disembarking and in the context of luggage accommodation. The output is easy-to-understand graphics on passenger changeover times, luggage stowage and seat usability.

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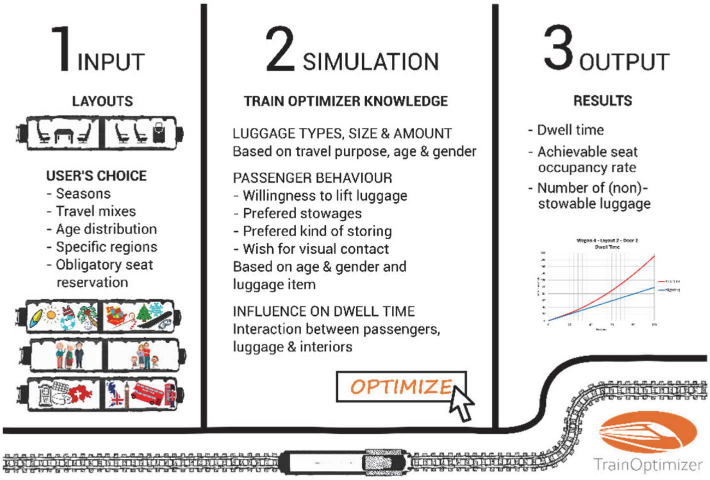

Figure 1 Simulation flowchart with TrainOptimizer® [1]

2 Passenger behaviour in relation to the layout

Relevant passenger behavior with a significant influence on efficiency in long-distance transport results from the carriage of luggage. This influences behavior when boarding and moving around the vehicle, when looking for a seat and when storing luggage. Sufficiently dimensioned luggage racks are essential and must meet the following two basic requirements of travelers:

- Travelers want to avoid lifting heavy luggage.
- For reasons of subjective safety, travelers want to always have visual contact with their own luggage.

In local transport, in addition to person-specific influences such as age or any mobility restrictions, the fact that people want to be able to reach the exit at any time and therefore avoid “unpopular” areas in the vehicles from which this is supposedly not possible is also decisive. This leads to irregular utilization of the vehicle and thus to reductions in the de facto vehicle capacity with equally negative effects on the passenger changeover time.
There must be good passenger flow inside the vehicle. The aisle width, the distance between the seats, the accessibility of the seats or, conversely, a high proportion of hard-to-reach seats, the presence or absence of luggage racks have a significant influence on the flow of passengers inside the vehicle. Unfavorably designed interiors quickly result in a backlog, for example when a person wants to get to a free window seat (see Figure 2) [1].

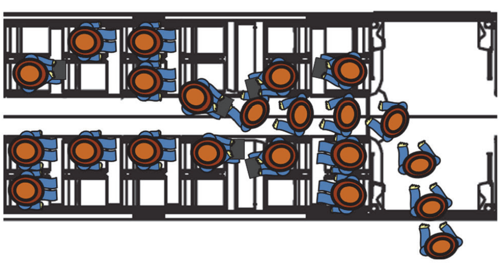

Figure 2 Backlog due to a cramped interior [1, 2]

In both long-distance and local transport vehicles, the arrangement and size of the doors also has a significant influence on the passenger changeover time. If a division of the passenger flow can be achieved after boarding a vehicle, the passenger changeover time is significantly accelerated. In addition, the door width should be at least 90cm for long-distance trains and at least 160cm for local trains in order to further speed up the passenger changeover. As a rule, door widths up to approx. 140cm barely allow two parallel walking lanes, while doors from 160cm have the full boarding capacity of two single doors.
Other noticeable influences on the passenger changeover time are the number of boarding steps and the passenger flow in the interior. A level boarding with gap bridging represents the ideal situation here; a gap extends the passenger changeover time by 1/10 sec per person. If, on the other hand, there is one or more steps, the passenger changeover time can be multiplied, especially in combination with luggage transport. An “open” area, e.g. in the form of a small multi-purpose compartment, should be provided on both sides of the boarding area (if the door arrangement allows passengers to flow in both directions) for passenger flow in the interior. The adjoining aisles should have an aisle width of at least 60 cm [3].
Doors arranged in such a way that the flow of passengers can split into two directions after boarding have a very positive effect. A possible backlog from inside the vehicle (see Figure 2) can thus be reduced because the boarding passengers have two routes available and then continue in the direction in which the backlog takes less time (see Figure 3) [1].

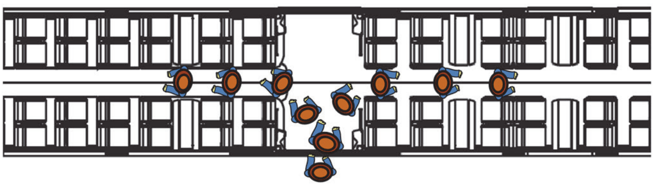

Figure 3 Division of the passenger flow [1, 2]

As mentioned earlier, doors with a width of 160cm or more significantly help to reduce the passenger changeover time. Whereas with doors up to 140cm the majority of passengers board one behind the other or offset to each other, with a door width of 160cm most passengers aboard the vehicle side by side, resulting in two walking lanes (see Figure 4). The time required for boarding per person is reduced from 1.3 seconds to 0.75 seconds. However, if the vehicle interior is cramped (as in Figure 4), then splitting the passenger flow does not help, as the backlog from the interior immediately builds up to the door [1].

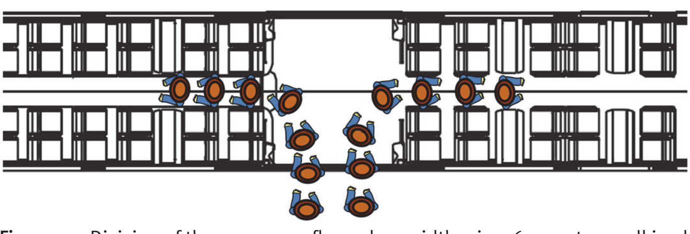

Figure 4 Division of the passenger flow - door width min. 160cm - two walking lanes [1, 2]

In order to achieve the time advantage of the wide doors, the doors must therefore be 160cm wide, there must be a standback area of at least 25cm to the left and right of the door and the interior must allow passengers to flow away easily on both sides (see Figure 6) [4].

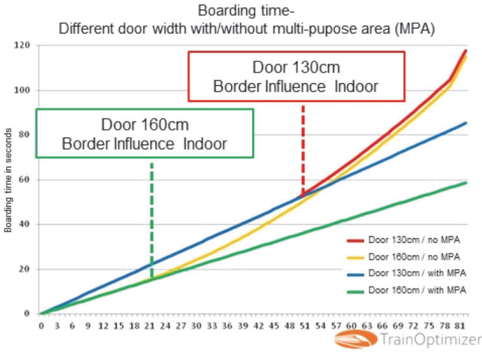

Figure 5 Boarding time, different doors and interiors [4]

Figure 5 shows the time required for boarding, once with a door width of 130cm and once with 160cm. In both cases, there is a cramped interior space without a multi-purpose area and with a multi-purpose area on both sides, which accelerates the passenger flow (see Figure 6). It can be seen that the passenger changeover is very fast with a door width of 160cm. However, if the interior is cramped, the passenger changeover time starts to increase due to the backlog despite the wide door. However, if the door is only 130cm wide, it is the bottleneck, no matter how well the passenger flow inside the vehicle works [4].

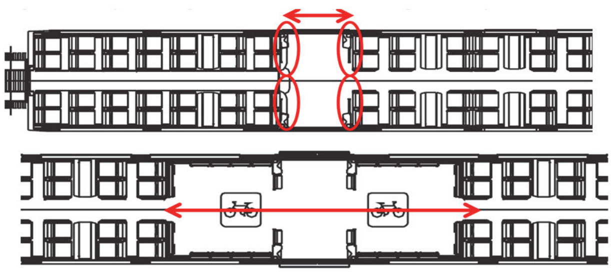

Figure 6 “Narrow” entrance vs. “wide” entrance [1, 2]

The free areas next to the doors also serve as multi-purpose areas for baby prams, wheelchairs, bicycles, luggage, etc., significantly speeds up the flow of passengers and increases capacity. Particularly regarding capacity, it is important to ensure that there are as few “unpopular seats” as possible [5]. Passengers want to get from their seat to the exit quickly, especially if there are a lot of passengers on the train. In those areas from which the exit is not easy to reach at peak times, there are fewer people, which reduces the capacity utilisation and thus the de facto capacity. Figure 7 shows an example vehicle. The red areas indicate low occupancy. These are mainly seats with a large distance to the door [6].

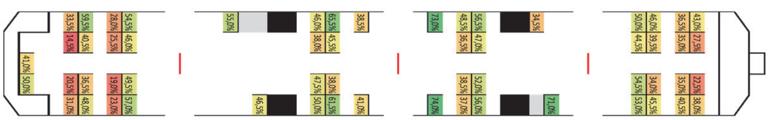

Figure 7 Accessibility of various areas [6]

In order to increase capacity and distribute passengers in the vehicle as evenly as possible, it is generally important to enlarge the boarding area and ensure that all seats have good accessibility to the door. One way of doing this is shown in Figure 8. With this layout, not only a high capacity is to be expected, but also a very fast passenger changeover [7].

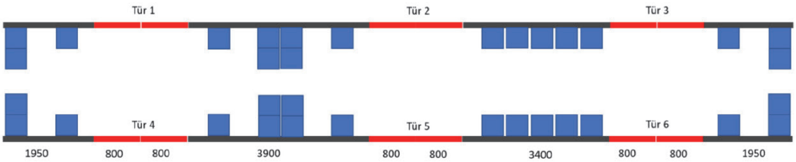

Figure 8 Efficient metro layout [7]

3 Effects on capacity and performance

The most important effects of the vehicle layout on capacity in terms of seats and, in local transport, standing room per train and performance as a measure of the number of trains per hour and thus the number of passengers per hour are shown below:

1) Vehicle layouts that include many "unpopular" areas in local transport and do not take sufficient account of the basic requirements for luggage storage, especially in long-distance transport, lead to a lower possible de facto utilisation per wagon and thus per train.
2) If the dwell time is extended as a result of the above-mentioned reasons, this leads to increased train running times with a corresponding reduction in performance, especially in local transport.

Conversely, an increase in capacity and performance can be achieved if:

1) Sufficiently dimensioned luggage storage facilities that meet passenger requirements are available, especially in long-distance transport. The actual seat availability can be increased by up to 20%.
2) There are no "unpopular" areas. In local transport in particular, these are areas with a longer route to the exit, where passengers are concerned that they will not be able to board the train in time.
3) layout measures that contribute to a reduction in dwell times and generally use vehicles with a high acceleration capacity. As a result, the train headway can be reduced, especially in local transport, and the number of trains per hour can be increased, taking into account other necessary infrastructure measures. For example, the stopping time on local services can be reduced by up to 20 seconds, which means a corresponding reduction in the train sequence and higher capacity.

In addition to the vehicle layout considerations, it is also important to carefully weigh up the general vehicle concepts in order to increase capacity. In particular, the use of double-decker trains and, ideally in combination, multiple-unit trains will lead to a further increase in train capacity.

4 Effects on railway operations, investment measures and energy requirements

The stopping time has an impact on railway operations on several levels. In order to increase efficiency, measures must be sought to help minimize stopping times. The vehicle layout has a significant influence on this, and in addition the technically required times for door release and door closing must be reduced and the operational handling procedure optimized.

<u>The most important positive effects of a minimized holding time are:</u>

1) Punctuality: The quality of service suffers when stopping times are extended, whereas minimized stopping times make a significant contribution to keeping to the timetable and therefore to punctuality. By reducing the stopping time, the buffer time is increased while the total journey time remains the same.

2) Edge journey times: The edge journey times are made up of half the dwell times in the neighbouring nodes and the journey time between the two nodes and are an essential feature of a synchronised timetable. As the edge journey time has a constant value (integer multiple of half the cycle time), a longer dwell time automatically requires a shorter journey time between the two nodes, which can only be achieved by a higher travelling speed. Conversely, the minimised dwell time in the stations can also reduce the travel speed. This has the following effects:
   a. Energy saving: The lower travelling speed saves energy. There is further potential for energy savings and the associated reduction in operating costs in the area of structural weight. Vehicles with long car bodies and two bogies each have a higher total weight than articulated train concepts with Jacob's bogies or even single wheels. Such concepts allow the total weight of the train per seat to be further reduced, which leads to a corresponding reduction in energy requirements.
   b. Infrastructure expansions: The infrastructure is often adapted and expanded in order to achieve the journey time required to reach the edge journey times. If journey time reductions in the range of minutes are required to achieve the edge journey time, then these time gains can be achieved by reducing the dwell time, which may eliminate the need for expensive infrastructure measures.
   c. Vehicle savings: For various rotations, especially in the area of local transport, a reduction in dwell time, especially with many intermediate stops, can lead to a reduction in the total journey time, which means that there is potential to save one or more vehicles in the entire rotation while maintaining the same service.

5 Conclusion

The dwell time is an important lever for increasing operational efficiency. Shorter dwell times in a synchronized timetable mean lower required travel speeds with the corresponding potential for energy savings, higher travel time reserves and thus improved punctuality and, conversely, offer the possibility of reducing the travel time to achieve the required edge travel times and help to avoid potentially expensive infrastructure expansions. In order to reduce the dwell time to generate the above-mentioned benefits, the following factors must be taken into account:

- Sufficient and properly designed luggage racks
- Avoid unpopular areas, especially in local transport vehicles
- The door arrangements must be selected in such a way that the passenger flow can be divided after boarding.
- There should be as few steps as possible, ideally a level boarding with gap bridging
- Door widths must be at least 90cm for long-distance transport and at least 160 cm for local transport
- After the boarding area, good passenger flow must be ensured, with aisle widths of at least 60 cm and open areas such as multi-purpose compartments at the beginning of the aisle.
- Vehicle concepts such as double-decker trains, multiple-unit trains and trains with shorter car bodies and Jacob's bogies or single wheels lead to a reduction in structural weight per passenger with corresponding energy efficiency. Such vehicles also largely increase capacity.

If the above-mentioned design rules for rail vehicles are fully taken into account from the outset, the efficiency of the railway system can be significantly increased without additional expense, as an increase in capacity, lower energy requirements, higher punctuality and possibly the avoidance of more expensive line extensions can be achieved.

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